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(54) POWER PLANT COOLING SYSTEM

(71) We, GENERAL ATOMIC COMPANY, a partnership organized under

the heat removal means may be an open circuit coolant system drawing water from

PATENTS ACT 1949

SPECIFICATION NO 1555408

The following corrections were allowed under Section 76 on 6 March 1980:

Page 7, line 95, *after* said *delete* precooler *insert* heat removal means

Attention is also directed to the following printers error:-

Page 7, line 14, *after* therein, *insert* and

THE PATENT OFFICE
3 April 1980

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electrical generating facilities, employ heat removal means for removing heat from the working fluid at a particular point in the working fluid cycle. For example, in the working fluid cycle of a steam power plant, such as a steam engine or steam turbine plant, a "condenser" is utilized to reject waste heat from the working fluid before it is returned to the primary heat exchanger or boiler. Similarly, in a gas turbine system, heat is removed from the gas in the cycle prior to returning the gas to the compressor. In the gas turbine system, this is accomplished by a device known in the art as a "precooler".

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back to the atmosphere. ... of the heat exchanger on the air results in a natural convection flow of air upwardly through the funnel structure drawing air inwardly near the bottom of the funnel.

In most areas, particularly arid or semi-arid areas, daytime temperatures are significantly higher than nighttime temperatures. For example, in desert regions, air temperatures at ground level during the day may reach temperatures in excess of 125°F which reduces the available temperature difference between the ambient and the required condensing temperature.

Thus, where atmospheric air is used as a heat sink, the plant performance is much influenced by the ambient temperature. In

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(72) Inventors DAVID CARLTON MORSE
DANIEL LEROY VRABLE
ROBERT EDWARD POTTHOFF and
HERMAN PETER FAY

(54) POWER PLANT COOLING SYSTEM

(71) We, GENERAL ATOMIC COMPANY, a partnership organized under the laws of the State of California, United States of America, of 10955 John Jay Hopkins Drive, San Diego, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a cooling system for a power plant which employs a working fluid circuit having heat removal means therein, such as a condenser in the case of a steam power electrical generating facility or a precooler in the case of a gas turbine power electrical generating facility. More particularly, the invention relates to an improved apparatus and method for cooling the heat removal means.

Many types of power plants, particularly electrical generating facilities, employ heat removal means for removing heat from the working fluid at a particular point in the working fluid cycle. For example, in the working fluid cycle of a steam power plant, such as a steam engine or steam turbine plant, a "condenser" is utilized to reject waste heat from the working fluid before it is returned to the primary heat exchanger or boiler. Similarly, in a gas turbine system, heat is removed from the gas in the cycle prior to returning the gas to the compressor. In the gas turbine system, this is accomplished by a device known in the art as a "precooler".

If the power plant is situated in a region wherein adequate water supplies are available, the cooling circuit employed for the heat removal means may be an open circuit coolant system drawing water from and returning it to a local body of water, an evaporative type cooler, or some other suitable type of heat exchanger. In water scarce regions, however, or in regions where thermal pollution cannot be tolerated in the water supply, other types of cooling may be required. One such type of cooling is the so-called dry cooling tower wherein an internal heat exchange structure is utilized to provide an interface between the material being cooled and flowing air drawn from the ambient atmosphere. The air may be caused to flow by natural convection or may be caused to flow in forced air systems by fans. In the former type of system, a large funnel structure is typically employed surrounding the heat exchange structure, with the funnel structure having an opening near ground level into which air is drawn, and having a top opening from which air is discharged back to the atmosphere. The warming effect of the heat exchanger on the air results in a natural convection flow of air upwardly through the funnel structure drawing air inwardly near the bottom of the funnel.

In most areas, particularly arid or semi-arid areas, daytime temperatures are significantly higher than nighttime temperatures. For example, in desert regions, air temperatures at ground level during the day may reach temperatures in excess of 125°F which reduces the available temperature difference between the ambient and the required condensing temperature.

Thus, where atmospheric air is used as a heat sink, the plant performance is much influenced by the ambient temperature. In

these circumstances, plant efficiency and output may be adversely influenced by a high ambient temperature. The result is that higher daytime temperatures means poorer performance of the system than during the night. Since maximum electrical load usually occurs during the day, this situation is the reverse of what is most desirable.

Conversely, during the night time, electrical load demand is normally reduced substantially while at the same time ambient temperature is also reduced resulting in relatively high overall efficiency or cooling capacity for the system. Thus, the lowest load demand coincides with the maximum plant output or efficiency based upon ambient air temperature.

It is an object of the present invention to provide an improved cooling system for a power plant of a type including heat removal means which in turn requires cooling.

Another object of the invention is to provide such a cooling system as well as a method of operating such a cooling system in which available cooling capacity may be stored and then selectively used during periods of peak electrical demand.

Another object of the invention is to improve the performance of a dry cooling tower by eliminating the adverse effect of the coincidence of peak load demand and peak daytime air temperatures.

A further object of the invention is to improve the performance of a dry cooling tower by employing means to selectively employ excess cooling capacity of the tower for producing and storing low temperature fluid which in turn may be selectively employed as needed for increasing the cooling capacity of the coolant circuit including the dry cooling tower.

In accordance with the invention, there is provided a cooling system for a power plant, the power plant having heat removal means in a working fluid circuit, comprising a closed loop primary coolant circuit for circulating a coolant through said heat removal means, said primary coolant circuit including a primary heat exchanger for cooling the coolant therein, and additional heat exchanger means arranged for selective operation in series with said primary heat exchanger, said additional heat exchanger means including means for selectively employing excess cooling capacity of said primary heat exchanger for producing and storing low temperature fluid for subsequent use to supplement the relative cooling capacity of said primary heat exchanger.

Also in accordance with the invention, there is further provided a method of operating a cooling system for a power plant, the power plant having heat removal means in a working fluid circuit, and the cooling system having a closed loop coolant circuit incorporating a dry cooling tower for circulating a coolant through the heat removal means, said method being characterized by the steps of selectively providing additional cooling capacity in combination with said dry cooling tower when the cooling capacity of the dry cooling tower is relatively low and selectively employing excess cooling capacity of said dry cooling tower to produce and store low temperature fluid for subsequent use in the preceding step.

The invention will be explained further with particular reference to the accompanying drawings wherein:

Figure 1 is a schematic layout of a power plant including a coolant system according to the present invention.

Figure 2 is a plot illustrating various performance parameters for a typical power plant provided with a cooling system in accordance with the invention.

Figure 3 is a schematic diagram of a closed cycle gas turbine system having a coolant system constructed in accordance with the present invention and used in connection with a nuclear reactor system.

Very generally, each of the power plants illustrated respectively in Figures 1 and 3 employs a heat removal means, either a condenser or precooler, arranged in a working fluid circuit. A coolant circuit circulates coolant through the heat removal means and through a dry cooling tower in a closed loop. In the embodiment of Figure 1, a storage pond is series connected in the closed loop coolant circuit, the pond preferably having a volume equal to at least about an eight hour supply of coolant. The coolant is circulated from the storage pond to the heat removal means and from the heat removal means through the dry cooling tower and back to the storage pond. The storage pond includes means for providing first-in, first-out flow whereby a delay of substantially a half-day may be provided by the coolant circuit.

Similarly, the closed cycle gas turbine system illustrated in Figure 3 includes turbine means 111 and compressor means 112. A gas is circulated for expansion in the turbine means and for compression in the compresser means. A precooler 113 is employed to cool the gas prior to compression in the compresser means. A closed loop primary coolant circuit 114 circulates the coolant through the precooler and includes a primary heat exchanger 116, such as a dry cooling tower, for cooling the coolant in the primary coolant circuit. A secondary heat exchanger 117 is also provided and at least a portion of the primary coolant in the primary coolant

circuit may be selectively directed through the secondary heat exchanger for further cooling the primary coolant.

It is to be particularly noted that the cooling system for the power plant of Figure 1 may also be used for example in connection with a gas turbine system such as that illustrated in Figure 3. Similarly, the cooling system provided in Figure 3 may also be used in connection with any power plant, for example, a steam power plant such as that illustrated in Figure 1.

Referring now more particularly to Figure 1, a power plant incorporating the invention is illustrated schematically. Hot gases are circulated in ducts 11 through a primary heat source 13. In the illustrated embodiment, the primary heat source may comprise a nuclear reactor or a fossil fuel burning furnace. The hot gases in the ducts 11 are circulated through two heat exchangers 15 and 17. The heat exchanger 15 comprises a reheater and the heat exchanger 17 comprises an evaporator-economizer and superheater, all of which are well known in the art. The hot gases are then returned through the ducts 11 to the primary heat source 13.

The working fluid circuit 19 operates to circulate the working fluid, in the illustrated embodiment steam, from the evaporator-economizer-superheater 17 to the high pressure or first stage steam turbine 21. After expansion in the turbine 21, the steam is circulated back through the reheater 15 and returned to a low pressure or second stage turbine 23 where additional work is withdrawn from the steam.

The working fluid circuit further includes a condenser 25 to which the working fluid is circulated after expansion in the turbine 23. As is known in the art, the condenser is utilized to remove heat from the steam and condense same to water to be returned, by a pump 27, to the evaporator-economizer-superheater 17. The condenser 25 thus serves as the heat removal means in the working fluid circuit 19.

For the purpose of cooling the heat removal means or condenser 25, a coolant circuit 29 is employed. The coolant circuit is a closed loop in which a dry cooling tower 31 is series connected through a thermal capacitor pond 33 and back to the condenser 25 by means of a pump 35. A bypass or shunt 37, controlled by a two-way selector valve 39 which can variably control the flow to the pond and/or bypass as desired for reasons set forth below.

In the cooling system of the invention, the circulating coolant which is cooled during the night, when the ambient air is cooler, is delayed in its circulation until the daytime when higher temperature ambient air is present and when, typically, the demand on the power plant is at its maximum. By providing a thermal capacitor pond 33 of sufficient size, substantially a twelve-hour or half-day delay can be imparted to the circulating coolant. During the nighttime hours, when less power demand is present, the higher temperature coolant cooled during the daytime hours in the dry cooling tower is circulated to the condenser. If during the nighttime hours the required power demand is sufficiently low, the excess cooling capacity in the dry cooling tower 31 is then available to even further cool the coolant so that even lower condenser temperatures and higher power output are available the following day.

By sizing the thermal capacitor pond 33 to hold approximately eight to ten hours of cooling water output from the condenser 25, a delay of substantially half a day may be provided. In extremely arid areas, it is desirable to provide an evaporation barrier such as a cover floating on the surface of the thermal capacitor pond 33 to minimize evaporation losses. In areas of limited water supply, spray nozzles (not shown) may be provided on the top of the pond 33 to provide additional cooling during peak hot periods and a movable cover (not shown) with drain holes may be provided to prevent evaporation during the rest of the year. The use of the selector valve 39 allows cooling water to bypass the pond during relatively short periods when the cooling system is used in the conventional way, or when averaging of coolant temperature is desired as is explained below.

By way of example, a power plant with approximately 1800 MW or reject heat and assuming a normal design condition temperature difference between the condensing temperature and the ambient air temperature of 50°F, a pond sufficient to store ten hours of coolant output from the condenser requires a capacity of approximately 1400 acre feet. Such a pond may be, for example, 40 feet deep by 36 acres in surface area. The optimum pond size is typically large for optimum utilization of the more costly dry cooling tower.

In the illustrated embodiment, the pond is provided with a plurality of internal baffles 41 for the purpose of ensuring a first-in first-out utilization of the coolant. Thus, mixing of the water in the pond is minimized. As an alternative to the use of baffles, the pond may be utilized in a way that the coolant is thoroughly mixed to provide a more constant pond temperature throughout the day, thereby approaching the daily mean. As a result, a more constant plant power output will result. The illustrated design, however, provides a plant output which more nearly matches the daily demand

profile and also provides a higher maximum output during the day.

Referring now to Figure 2, the daily plant power output curve for the foregoing described example is plotted for a given hot day air temperature profile and assumed operating condition. The temperature profile shown in Figure 2 is based on a maximum daytime temperature of 100°F at 3 p.m. with a minimum nighttime temperature of 60°F occurring at 3 a.m. Thus, a daily temperature variation totalling 40°F exists, which is typical of may areas in arid regions of the Western United States. From approximately 10 a.m. to 7 p.m., a net cooling effect is required from the pond 33 since the ambient air temperature is above the daily average. From about 9 p.m. to 8 a.m., there is net heat removal from the pond since the ambient air temperature is below average. During the period around approximately 8 a.m. and once again at approximately 8 p.m., cooling is not required since the ambient air temperature is at approximately the average temperature. Under these conditions, the selector valve 39 may be utilized to bypass coolant around the thermal capacitor pond 33.

During the periods from 9 p.m. to 8 a.m. and from 10 a.m. to 7 p.m., all of the coolant is passed through the thermal capacitor pond 33 in series with the dry cooling tower 31 and the condenser 25. In the example, water cooled by the cooling tower 31 does not flow through the condenser 25 until 12 hours later. Thus, water cooled in the tower at 3 a.m. does not reach the condenser 25 until 3 p.m. and conversely, water cooled in the tower at 3 p.m. does not reach the condenser until 3 a.m. In this way, the temperature cycles in the coolant are twelve hours out of phase with the daily ambient air temperature. Thus in Figure 2, the daily range in condenser inlet water temperature is only approximately 13°F even though the ambient temperature range is 40°F. The maximum inlet water temperature occurs at night and is only 112°F even though the daytime air temperature reaches 100°F. This compares with a maximum condensing temperature of 135°F for a typical conventional dry cooling plant without a thermal capacitor pond.

As may also be seen from Figure 2, the daily gross generator power output of the plant of the example has a peak around 8 a.m. and stays relatively high during the course of the day, reaching a maximum about 6 p.m. The output power curve then declines to a lower level during the night. The resulting shape of this curve is the inverse of a conventional dry cooling plant not utilizing a thermal capacitor pond.

A further variation in operating the cooling system of the invention may accrue from bypassing only a portion of the coolant through the selector valve 39. By selecting the proper level, for example approximately 50% flow through the bypass, the resulting mix with the pond water provides a nearly constant coolant temperature and therefore a nearly constant power output for the power plant.

The present invention is also applicable to solar power plants situated in arid regions where dry cooling is required. Since solar plants may be mid-range peaking plants producing most of their power during the day when the sun is shining and producing little or no power at night, the need for cooling peaks during the daytime hours. However, since the greater dry cooling capacity exists at night when the air is coolest, the present invention can be used effectively.

More particularly, by utilizing the present invention, the cooling tower may be used at night to cool the water in the capacitor pond. Since electrical load on the solar plant will typically be low at night, the cooling will be relatively efficient. The cool water thus stored in the pond is then available to cool the plant next day when the plant is operating at or near full load. In this way, the effect of peak daytime air temperatures is not felt by the cooling system, and the dry cooling tower may be designed for nighttime air temperatures instead. Other types of mid-range peaking power plants in addition to those discussed herein and operating primarily during the day may effectively utilize the invention.

Referring now more particularly to Figure 3, the closed cycle gas turbine system illustrated therein is employed in a nuclear reactor system of the high temperature gas-cooled type. High temperature gas-cooled reactors are known in the art and will not be described in particular detail herein. The reactor system of Figure 3 includes a prestressed concrete reactor vessel 121 which encloses the reactor 123 and its associated structures and ducting, not shown, and in which the closed cycle gas turbine system is also enclosed.

The primary reactor coolant is preferably helium and in a system wherein the reactor is of approximately 3,000 megawatts thermal capacity, it can be expected that the inlet temperature of the helium is approximately 927°F (497°C) and that the outlet temperature of the helium is approximately 1500°F (816°C). A coolant gas inventory control system 127 is provided through which some of the coolant gas may be bled off or bled in to thus regulate the total inventory of coolant gas in the reactor system. This also regulates the overall

operating pressures within the closed gas cycle gas turbine system.

The closed cycle gas turbine system includes the turbine 111 and the compressor 112, each of which may be a single stage or multiple stage as desired. A shaft connection 129 or other suitable mechanical drive means couples the turbine 111 to the compressor 112. Similarly, a shaft connection 131, having suitable seals, not shown, passes out of the reactor vessel 121 to a generator 133 for producing electrical power.

The precooler 113 is used for cooling the gas prior to compression in order to reduce the amount of work necessary to compress the gas. The closed loop primary coolant circuit 114 is employed for the precooler 113 which circulates coolant from outside the reactor core through the precooler 113. The primary heat exchanger 116, which is illustrated as a dry cooling tower, is connected in series in the primary coolant circuit and cools the water flowing in the primary coolant circuit by the flow of air, indicated by the arrows 135. Preferably, the primary coolant circuit is pressurized to permit the water therein to be heated above the atmospheric boiling point. Typical operating temperatures may be an inlet temperature to the heat exchanger 116 of 280°F (138°C) and an outlet temperature from the heat exchanger 116 of about 85°F (29°C).

The turbine 111 provides all the necessary power to drive the compressor 112 and also drives the electrical generator 133. As the working gas leaves the turbine 111, all useful work has been extracted insofar as expansion is concerned. Nevertheless, the gas exiting the turbine 111 still has a substantial amount of thermal energy. This thermal energy is transferred to the compressed gas prior to its circulation through the reactor 123 by the use of a recuperator 139. Typical temperatures of gas exiting the turbine 111 are about 990°F (532°C). In a suitable constructed recuperator, the temperature of the gas prior to entry into the precooler 113 may be dropped to about 441°F (227°C) and the temperature of the compressed gas exiting the compressor 112 may be raised from about 350°F (177°C) to about 927°F (497°C).

In operating the illustrated system, gas passes through the reactor 123 and enters the turbine 111 for expansion. After expansion, some of the heat from the gas is extracted as it passes through the recuperator 139 and enters the precooler 113. In the precooler 113, the gas is cooled down for compression in the compressor 112. After compression in the compressor 112, the gas is circulated back through the recuperator to increase its temperature and then passes down through the reactor 123 once more.

The precooler coolant circuit is a closed loop circuit in which the circulating power is provided by a pump 143. Output from the pump 143 may be directed through a valve 145 to the precooler 113, and from there returned to the input side of the heat exchanger or dry cooling tower 116.

The precooler coolant circuit includes an additional loop in which is positioned a secondary heat exchanger or after-cooler 117. The output of the pump 143 may also be applied to the after-cooler 117 and a valve 149 completes the extra loop in the primary coolant circuit to enable the output of the after-cooler 117 to be returned to the precooler 113.

The secondary heat exchanger 117 is also connected in a secondary coolant circuit 152 including a pump 153, a valve 155, and a delay reservoir 157. The size of the delay reservoir 157 is selected to provide a quantity of coolant in the secondary coolant circuit sufficient to provide for circulation of coolant therethrough in a single pass over a substantial period of time, for example, 8 hours in the distance discussed below. Baffles 159 inside of the reservoir 157 prevent mixing of the incoming coolant with the outgoing coolant to allow for a temperature gradient between the outgoing coolant and the incoming coolant for reasons which will be explained below.

A refrigeration system 161 is provided for cooling the secondary coolant in the secondary coolant loop. For this reason, the secondary coolant loop includes an evaporator 163, the inlets and outlets of which are controlled by valves 165 and 167, respectively. The refrigeration system also includes a compressor 169 and a condenser 171 providing a tertiary coolant loop. A bypass 173 including a control valve 175 directs coolant from the output of the after-cooler 117 in the primary coolant circuit through the condenser 171 of the refrigeration circuit 161 and back to the inlet of the heat exchanger or dry cooling tower 116, for reasons which will be explained below.

During periods of normal load demand and mean ambient temperatures, the system of the invention may be operated in a so-called normal mode. In this condition, the valves 149 and 175 are closed and the valve 145 is open. In this condition, the primary coolant in the primary coolant circuit flows through the precooler 113, is cooled adequately in the heat exchanger or dry cooling tower 116, and is pumped back to the precooler through the valve 145 by the pump 143.

During what is typically an eight-hour

period in the middle of the day, peak load demand occurs. Unfortunately, this period usually coincides with the period of highest ambient temperature. Therefore the ability of the heat exchanger or dry cooling tower 116 to cool the primary coolant in the primary coolant circuit is lessened. To compensate for the lessening of the cooling capacity of the dry cooling tower 116, the system is operated in a so-called peak load mode. In this mode of operation, the valves 145 and 175 are closed whereas the valve 149 is open. In this condition, the after-cooler 117 is included in the primary coolant circuit with the pump 143 providing the output of the dry cooling tower 116 to the after-cooler 117. The output of the after-cooler 117 then circulates back to the precooler through the valve 149. At the same time, circulation of secondary coolant in the secondary coolant loop 152 through the after-cooler 117 provides cooling of the primary coolant. In this mode of operation, the valves 165 and 167 are closed whereas the valve 155 is open.

By providing sufficient delay capacity in the reservoir 157, the period of time during which cold coolant is available for circulation through the after-cooler may be as required. Typically, eight hours will be sufficient to provide the necessary cooling in the after-cooler 117 over the period of time during which peak load occurs. Thus, the operating efficiency of the gas turbine system is maintained at a high level as a result of adequate cooling in the precooler 113 to meet peak load requirements.

During the cooler night-time periods, electrical load demand is substantially reduced. During this period the invention takes advantage of the low demand load to cool the coolant in the secondary coolant circuit for storage and further use during the period of peak demand. In the low load demand mode, the valve 149 is closed and valve 145 is regulated such that only the amount of coolant necessary to provide the proper cooling in the precooler 113 is directed thereto and circulated back to the dry cooling tower 116. Because of the low electrical demand during the low ambient temperatures of night-time, the plant output is reduced and the capability of the dry cooling tower to provide the necessary cooling may typically require only about 40% of the circulating water coolant capacity.

The remaining portion of the coolant, for example 60% is circulated through the after-cooler 117. Return is provided by opening the valve 175 and directing the coolant through the bypass 173 and thereby through the condenser 171. Coolant then returns to the inlet side of the dry cooling tower 116.

Thus circulated, the cooling effect of the dry cooling tower 116 is used to assist in cooling the secondary coolant in the secondary loop by passing through the after-cooler 117. The cooling effect of the dry cooling tower is used also to assist the operation of the refrigeration system 161 by withdrawing heat from the refrigerant in the system 161 through the condenser 171.

At the same time, the valve 155 is closed and the valves 165 and 167 are open so that the secondary coolant in the secondary coolant circuit is passed by the pump 153 through the evaporator 163, thus providing additional cooling of the secondary coolant by the refrigeration system 161. The power required to operate the refrigeration system through operating the compressor 169 is thus utilized during the period of low electrical load demand. Accordingly, the secondary coolant in the secondary coolant circuit is chilled and stored in the delay reservoir 157 for use during the peak load demand period.

Assuming a maximum daytime temperature of 95°F (35°C) mean and a minimum night-time temperature of 65°F (19°C) mean, the system of the invention is capable of increasing the performance of a gas turbine high temperature gas-cooled reactor system by 100 mw(e) output during an eight-hour period. This increase in power output can be adjusted to coincide with the peak electrical load for each day, thus effectively using the stored night-time capacity during the peak electrical demand period. Typically, the primary and secondary coolant will be water, whereas the coolant in the refrigeration system will be ammonia or some other suitable refrigerant. The primary coolant will typically be pressurized at approximately 300 psia (20 kg/sq.cm.) whereas the secondary coolant will typically be at or close to atmospheric.

In comparing the embodiments of Figures 1 and 3, it may be seen that the precooler 113 in Figure 3 serves as the heat removal means in the working fluid circuit 121, corresponding to the function of the condenser 25 in the working fluid circuit of the embodiment of Figure 1. As was also indicated above, the cooling system components illustrated in Figure 1 may also be employed for example with the precooler 113 of Figure 3 and the cooling system components of Figure 3 may also be employed for example with the condenser of Figure 1. However, it will be apparent that the sizing and operating characteristics of various components in either cooling circuit might require modification in order to conform with the specific operating characteristics of a different power plant.

Various modifications of the invention in addition to those shown and described

herein will be apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

WHAT WE CLAIM IS:—

1. A cooling system for a power plant, the power plant having heat removal means in a working fluid circuit, comprising a closed loop primary coolant circuit for circulating a coolant through said heat removal means, said primary coolant circuit including a primary heat exchanger for cooling the coolant therein, additional heat exchanger means arranged for selective operation in series with said primary heat exchanger, said additional heat exchanger means including means for selectively employing excess cooling capacity of said primary heat exchanger for producing and storing low temperature fluid for subsequent use to supplement the relative cooling capacity of said primary heat exchanger.

2. The cooling system of Claim 1 wherein said additional heat exchanger means comprises a storage pond connected in series with said primary heat exchanger, said storage pond having a volume equal to at least a several hour supply of coolant and further characterized by means for circulating coolant to flow from said storage pond to said heat removal means and from said heat removal means through said primary heat exchanger and back to said storage pond, said storage pond including means for providing a first-in, first-out flow whereby a delay of substantially a half-day may be provided by said coolant circuit.

3. The cooling system of Claim 2 wherein said primary heat exchanger is a dry cooling tower.

4. A cooling system for a power plant according to Claim 3 being further characterized by a coolant bypass means for shunting a portion of the coolant flow around said storage pond.

5. A cooling system for a power plant according to Claim 1 wherein said power plant utilizes steam as a working fluid and wherein said heat removal means comprises a condenser.

6. A cooling system for a power plant according to Claim 1 wherein said power plant comprises a gas turbine power plant and wherein said heat removal means comprises a precooler.

7. A cooling system for a power plant according to Claim 1 being further characterized by means for selectively directing at least a portion of a primary coolant in said primary coolant circuit through said additional heat exchanger means for further cooling the primary coolant, said primary heat exchanger being a dry cooling tower.

8. A cooling system for a power plant according to Claim 7 being further characterized by a closed-loop secondary coolant circuit for circulating a secondary coolant through said additional heat exchanger means.

9. A cooling system for a power plant according to Claim 8 being further characterized by a refrigeration system for cooling said secondary coolant.

10. A cooling system for a power plant according to Claim 8 and being further characterized by a delay reservoir in said secondary coolant circuit for storing a quantity of the secondary coolant sufficient to provide cooling of primary coolant for a substantial period of time.

11. A cooling system for a power plant according to Claim 7 being further characterized by a closed-loop secondary coolant circuit for circulating a secondary coolant through said additional heat exchanger means, a delay reservoir in said secondary coolant circuit for storing a quantity of the secondary coolant sufficient to provide cooling of the primary coolant for a substantial period of time, said directing means including bypass means for selectively bypassing at least a portion of the primary coolant around said precooler and through said additional heat exchanger means for cooling the secondary coolant in said secondary coolant circuit.

12. A cooling system for a power plant according to Claim 11 being further characterized by a refrigeration system for cooling said secondary coolant.

13. A cooling system for a power plant according to Claim 12 being further characterized by a tertiary heat exchanger in said refrigeration system, said bypass means being coupled to said tertiary heat exchanger for transferring heat from said refrigeration system to the portion of the primary coolant circulated by said bypass means.

14. A method of operating a cooling system for a power plant, the power plant having heat removal means in a working fluid circuit, and the cooling system having a closed loop coolant circuit incorporating a dry cooling tower for circulating a coolant through the heat removal means, said method being characterized by the steps of selectively providing additional cooling capacity in combination with said dry cooling tower when the cooling capacity of the dry cooling tower is relatively low and selectively employing excess cooling capacity of said dry cooling tower to produce and store low temperature fluid for subsequent use in the preceding step.

15. A cooling system for a power plant

substantially as hereinbefore described with reference to the accompanying drawings.

16. A method of operating a cooling system for a power plant substantially as hereinbefore described with reference to the accompanying drawings.

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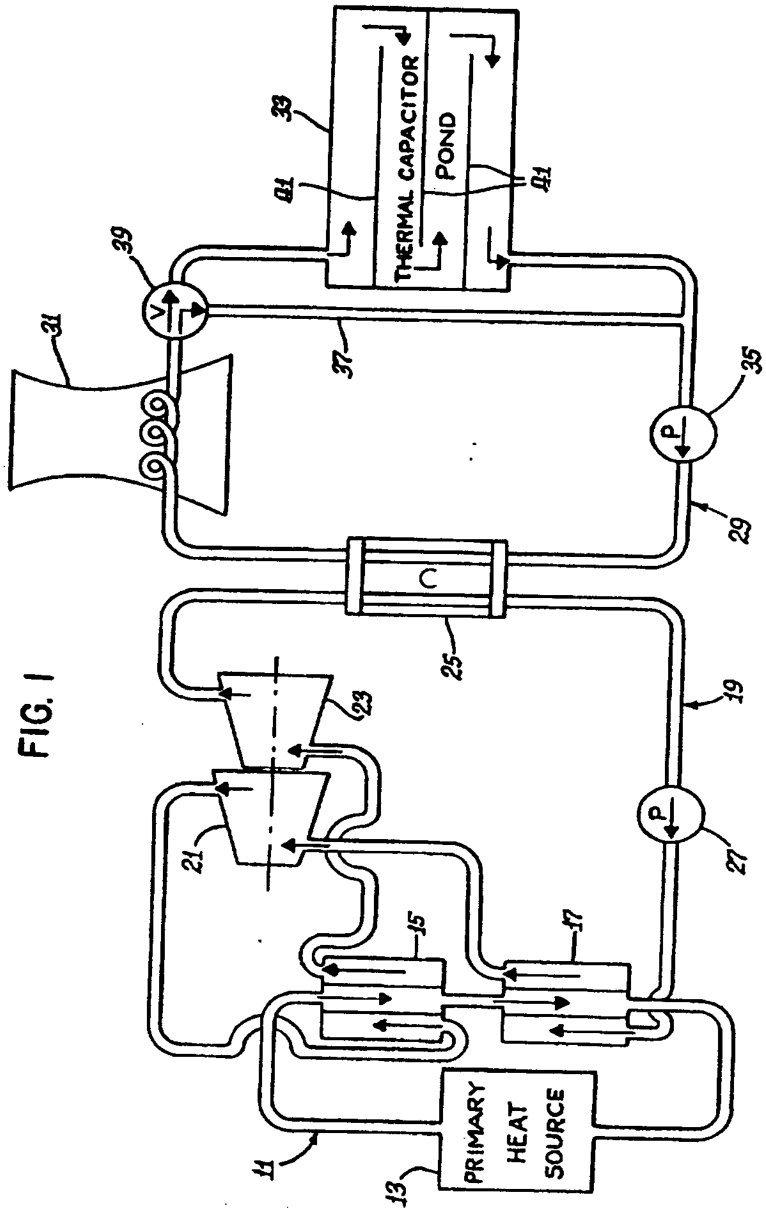
THERMAL CAPACITOR
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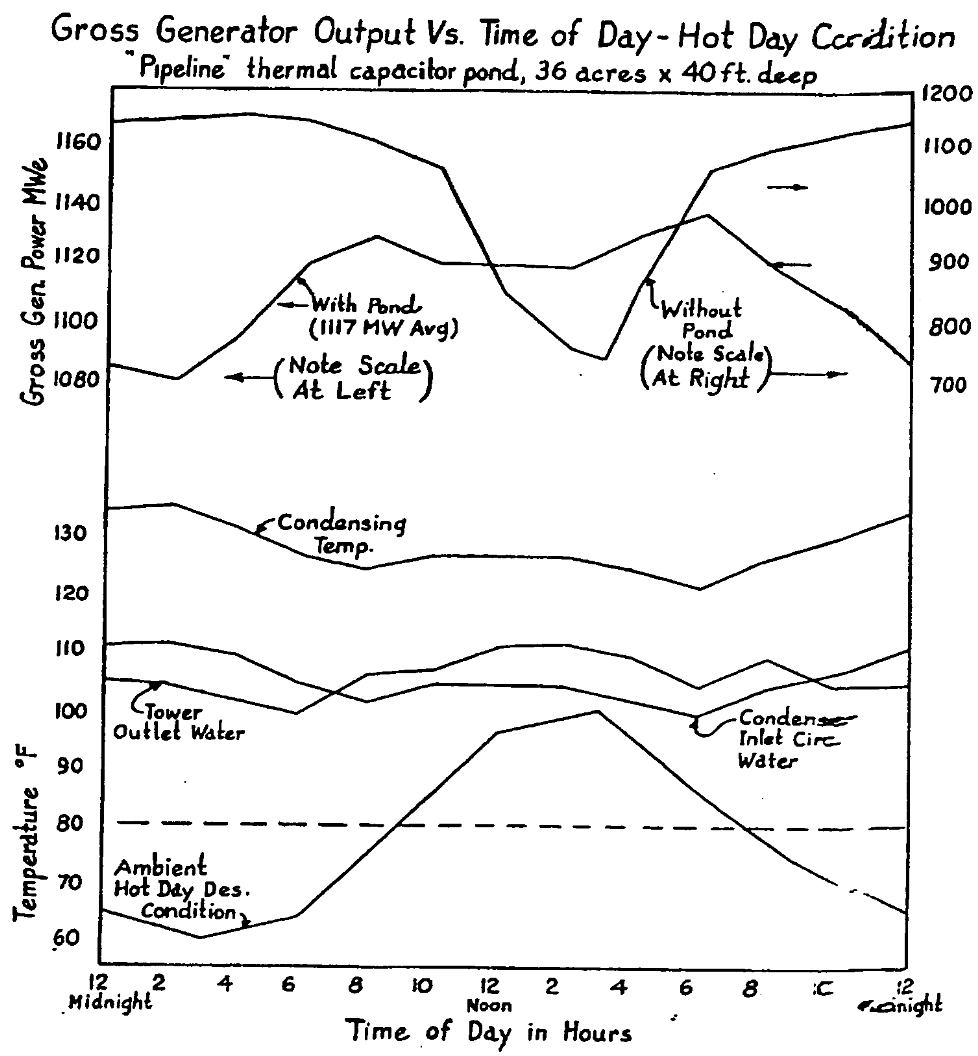
FIG. 1

FIG. 2


Gross Generator Output Vs. Time of Day - Hot Day Condition
"Pipeline" thermal capacitor pond, 36 acres x 40 ft. deep
Gross Gen. Power MWe
1160
1140
1120
1100
1080
1200
1100
1000
900
800
700
With Pond (1117 MW Avg)
(Note Scale At Left)
Without Pond
(Note Scale At Right)
Condensing Temp.
Tower Outlet Water
Condenser Inlet Circ. Water
Ambient Hot Day Des. Condition
Temperature °F
130
120
110
100
90
80
70
60
12 Midnight
2
4
6
8
10
12 Noon
2
4
6
8
12
Time of Day in Hours

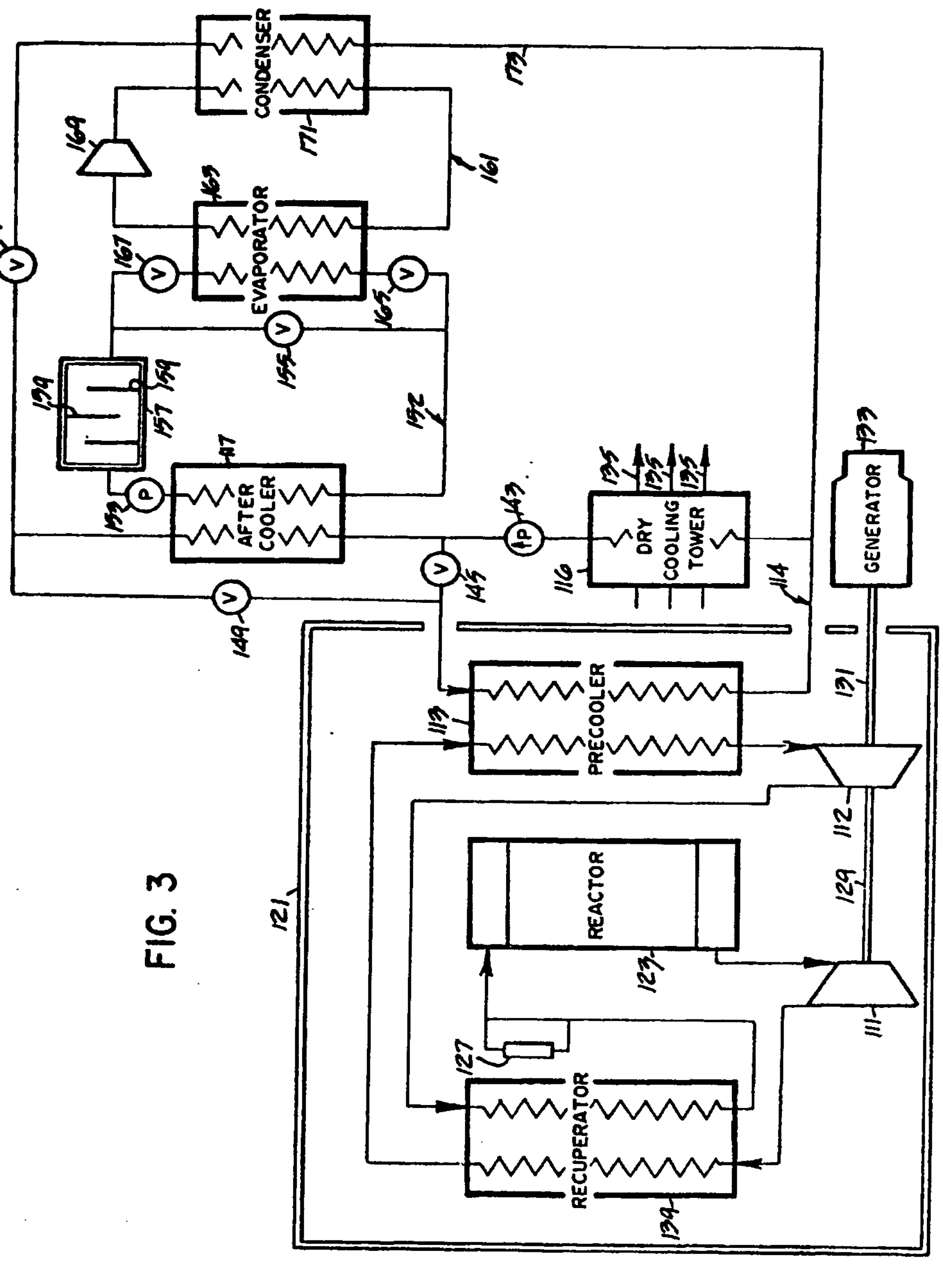

CONDENSER
EVAPORATOR
AFTER COOLER
DRY COOLING TOWER
GENERATOR
PRECOOLER
REACTOR
RECUPERATOR

FIG. 3